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FINAL REPORT

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**MECHANICAL HARVESTING OF SEA BUCKTHORN
(HIPPOPHAE RHAMNOIDES L.) - AN INTER-PROVINCIAL
STUDY**

**Funded by
The Agriculture Development Fund**

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Prepared by: Prairie Agriculture Machinery Institute

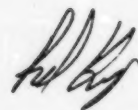
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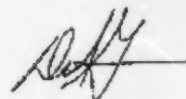
Mechanical Harvesting of Sea Buckthorn

An Inter-Provincial Study

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Acknowledgements

This project is being carried out jointly by the Prairie Agricultural Machinery Institute (PAMI), the University of Manitoba, the University of Saskatchewan, and the Prairie Farm Rehabilitation Administration (PFRA).

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Disclaimer

The data, analyses, interpretations, discussions, conclusions, and recommendations presented in this report are those of PAMI, and do not necessarily represent those of the Project Partners or Sponsors, including ADF and MRAC.

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1. Summary

The project team undertook to develop and test concepts to machine-harvest berries and leaves of the Sea Buckthorn shrub. Over the three-year project the team developed two concepts; one to successfully harvest berries, and the second to harvest leaves.

Berry harvesting was accomplished by tree shaking. This involved attaching a shaker mechanism to tree branches and subjecting them to vibration for periods up to 60-seconds. Vibration parameters of 1-inch (peak-to-peak) amplitude, and 25-Hz frequency were found to work best for optimum harvest and minimum damage. Timing of harvest operations in the fall was critical to berry yield and quality, and to minimize tree damage.

Leaf harvesting was accomplished by a rotating-brush device. The brush design found to work best had 0.04-inch diameter, 2.375-inch long plastic bristles on a 4.625-inch diameter hub, rotated at 350 RPM. This design produced an optimum harvest with minimal tree damage to bark, branches, and buds.

Large-scale embodiments of the concepts were tested and found to produce viable harvest performance. However, considerably more work is required to develop commercially viable machines.

The project team consisted of personnel from:

- The Prairie Agricultural Machinery Institute (PAMI)
- University of Manitoba, College of Bio-resource Engineering
- University of Saskatchewan, College of Agricultural and Bio-resource Engineering
- The Prairie Farm Rehabilitation Administration (PFRA) Shelterbelt Center

Project funding was provided by:

- Saskatchewan Agricultural Development Fund (ADF)
- Manitoba Rural Adaptation Council (MRAC)

2. Technical Report

2.1 Background

Sea Buckthorn (*Hippophae rhamnoides* L.) is a multi-branched thorny shrub that reaches 2-4 meters at maturity. It is deciduous, with narrow, silver-gray leaves (Li and Schroeder 1996). The fruit, produced in late August, is a yellow-orange berry that remains on the tree all winter.

While most of the interest in Sea Buckthorn concerns the berries' nutritional properties, there is also sufficient interest in the leaves to warrant investigation. The leaves contain a greater variety of vitamins and minerals than the berries, although in smaller quantities. Sea Buckthorn leaves are also a source of protein. Traditionally, the leaves have been used in animal feed for rapid weight gain and a shiny coat (Schroeder and Yao 1995). Sea Buckthorn leaves can also be dried for teas and processed for nutraceutical products.

Sea Buckthorn trees have been used for a number of years on the Prairies as shelterbelts. For an even longer time, Sea Buckthorn has been used in traditional medicines in Asia and Europe. Western nutraceutical markets are becoming very interested in Sea Buckthorn for its medicinal properties. Many products can be produced using the juices and oils from the Sea Buckthorn plant.

Alternative crops on the Prairies are needed, and the value of Sea Buckthorn as an alternative crop looks promising. Values of \$3.85/kg for the berries and \$11/kg for the leaves have been stated by Canadian enterprises dealing in these plant materials. Many areas utilize Sea Buckthorn as a shelterbelt, and harvesting the berries and leaves could serve to supplement farm income.

The development of the Canadian Sea Buckthorn industry is inhibited by the lack of mechanical harvesting equipment. Some harvesters have been developed for the berries (Olander 1998) but none had been developed for the leaves. In Eastern countries, the berries and leaves are harvested by hand. However, in Canada, manual labour is either unavailable or too expensive for producers, therefore, making Sea Buckthorn orchards a non-profitable venture.

2.2 Objectives

The objective of this project is to develop a mechanical leaf and berry harvester for the Sea Buckthorn plant. In addition to developing a harvester, the data gathered in the process of the study will be analyzed to help determine the optimum harvest time, and best methods of berry and leaf removal.

2.3 Overview: Project Activities

This development project was carried out in a sequence of activities over a 3 year period, beginning in 1999 and ending in 2002. The activities carried out include:

1999/00

- Individual branch shaker was developed and used in field tests to derive basic information for Sea Buckthorn.

2000/01

- Hand-held leaf harvester constructed and field-tested.
- Full-size berry harvester designed, constructed, and field-tested.
- Full-size leaf harvester designed.

2001/02

- Full-size leaf harvester constructed and field-tested.
- Full-size berry harvester modified and field-tested.
- Final report completed.

The activities were planned in the sequence shown to minimize technical risk. Information from early activities helped to determine feasibility of the various harvesting concepts and gave vital information to guide design of the larger, more costly machines developed later in the project.

2.4 Year 1999/00 Activities

Individual Branch Shaker

A shaker unit was designed and constructed that could be readily transported for field tests. The unit consisted of a hydraulically driven oscillator enclosed in a glass-fronted catch bin. The shaker unit is shown in Figures 1 and 2 below.

Oscillation frequency and amplitude could be varied. Frequency was measured using a magnetic pickup and meter. Frequencies used in the tests were:

- 464 cycles per minute
- 652 cycles per minute
- 840 cycles per minute
- 1200 cycles per minute
- 1500 cycles per minute

Amplitudes (peak-to-peak) used were:

- 0.50-inch
- 0.75-inch
- 1.00-inch
- 1.25-inch



Figure 1. Individual branch shaker used in amplitude and frequency tests on Sea Buckthorn Berry removal.

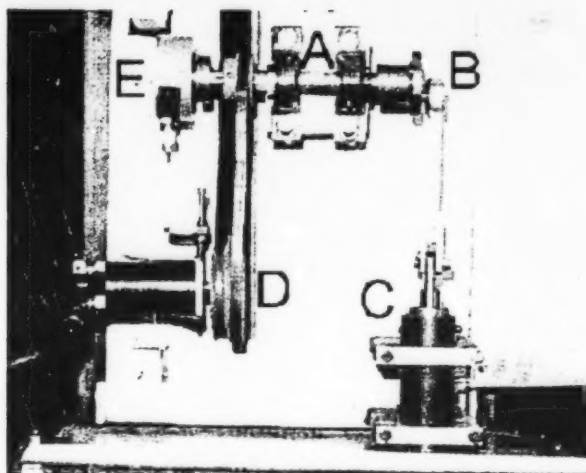


Figure 2. Cam mechanism within the stationary shaker Which provides the vertical shaking of the branch.

Method of Data Collection: A branch carrying berries was cut from the tree and fastened into the shaker apparatus. The branch length, from the attachment point on shaker arm to the first berry was measured and recorded. The shaker was then run at one of the preset frequencies and amplitudes for 15s. Berries removed during the 15s interval were collected in a plastic bag. The branch was shaken for an additional 15s and berries removed were collected in a second plastic bag. A third bag was used to contain the branch with the remaining berries. This sequence was repeated at each tree for each combination of frequency and amplitude. These tests occurred on the following dates: September 28, October 13 - 14, November 3 - 4, 1999 and January 13 - 14, 2000. All bags were transported immediately to PAMI's laboratory facility and refrigerated.

To analyze the performance data. The berries in each bag were first counted. The berries samples were weighed, and the pedicel length was measured. This data was then entered into a spreadsheet for further analysis, which is discussed, following. The spreadsheets are too large to include in this report. They can be made available on request, as Excel Files on CD.

Results and Discussion: Data from the four field tests was first grouped into an overall analysis to study the effects of frequency on berry removal. This analysis was done by selecting the best berry removal performance (regardless of amplitude), at each frequency, for each field test session. These were then averaged over all of the test sessions to illustrate overall performance trends over the frequency range. This analysis is shown in **Figure 3** below.

The figure shows that maximum berry removal tended to occur at the higher shaker frequencies. The 1200 cycle/min frequency tended to remove the most, with the 1500 cycle/min frequency producing only slightly lower performance.

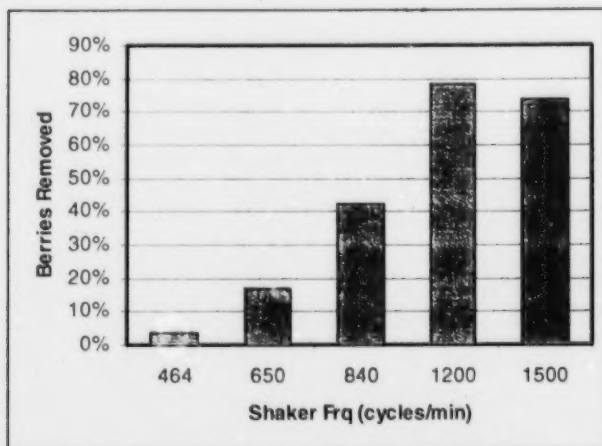


Figure 3. Berry removal at various shaker frequencies

A second analysis was performed that focused on the data generated at the frequency setting of 1200 cycle/min. In this analysis the berry removal performance of each of the shaker amplitudes was studied. This analysis is illustrated in Figure 4 below.

The figure shows that the higher amplitudes tended to give better berry removal. At 1200 cycles/min, a 1-inch amplitude gave best overall berry removal. The 1.25-inch amplitude gave slightly lower performance.

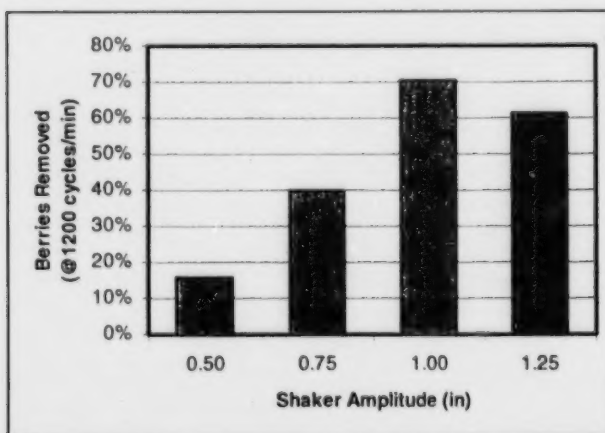


Figure 4. Berry removal at various shaker amplitudes and 1200 cycle/min frequency.

Shaking duration for berry removal was also studied by graphing the berries removed by each of the two 15 second shaking sessions as a percentage of total berries available. Although data was captured for all shaker frequencies and amplitudes, only those for the 1200 cycles/min frequency, and 1-inch amplitude were used in the analysis here. This data is shown in Figure 5 below.

The figure shows that, on average about 55% of the berries were removed in the first 15-seconds of shaking. Another 15% were removed in the next 15-seconds, for a total removal of about 70% over a 30-second period.

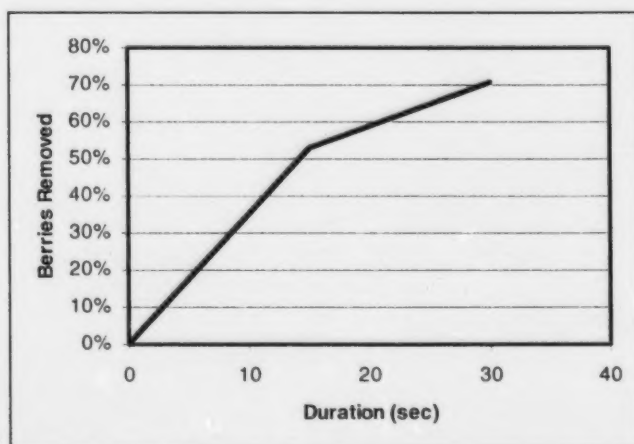


Figure 5. Berry removal over shaking duration.

Analysis was also conducted to determine what effect harvest date had on effectiveness of shaking for berry removal. Average removal over a 30-second period for each of the four harvest dates are shown in Figure 6 below.

The data indicates that as autumn progresses the removal of berries tends to increase. The data shows a rise from about 55% in late September to about 70% in early November. In mid winter berry removal in the same test plots tended to reduce back to those levels experienced in early autumn. The exact nature cause of this change in removal rate was not determined. However, the data suggests that the timing of berry harvest could have a substantial effect on the percentage of available fruit harvested.

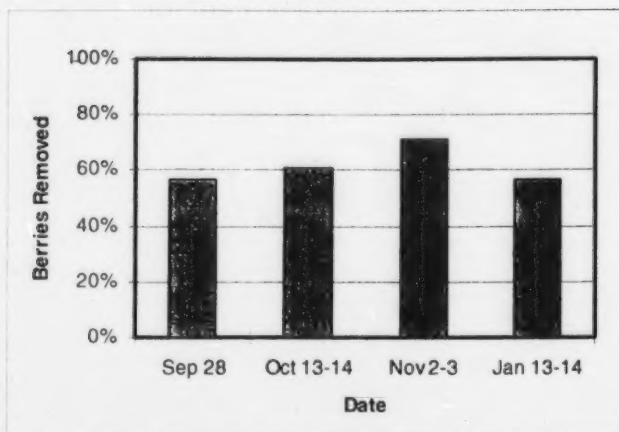


Figure 6. Berry Removal at various Harvest Dates.

Analysis was undertaken to determine the effect of harvest date on berry weight. Average berry weights were determined from test samples from each of the four harvest dates. These are shown in **Figure 7** below.

The figure shows that berry weight drops throughout the autumn season. The data shows a drop from 3.1 to 2.6 grams per berry from late September to early November. The data also shows a regain in berry weight in mid winter. A loss in berry weight over time seems logical, but the mid-winter regain cannot readily be explained. The data however, suggests that harvest timing can substantially affect berry weight.

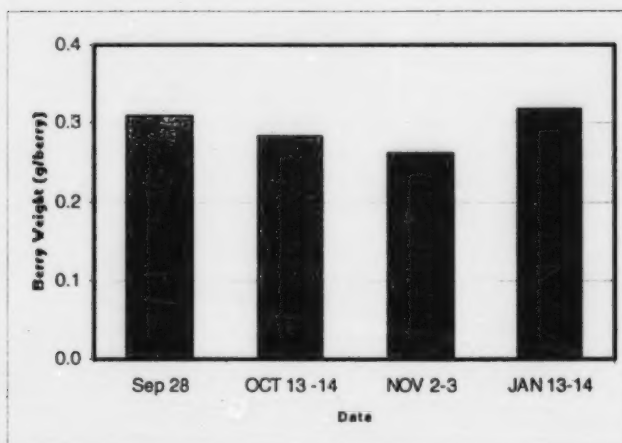


Figure 7. Berry Weight at various Harvest Dates.

Conclusions: Results of the berry harvest field tests on individual branches indicates that berries can be harvested over the autumn and winter seasons by branch shaking. A shaking frequency of 1200 to 1500 cycles per minute (20 to 25 Hz), at an amplitude of 1.0 to 1.25 inches appeared to be optimum for berry removal. At this frequency and amplitude range, branches may have to be shaken for 30 seconds or more to harvest more than 70% of the berries. Timing of berry harvest during autumn and winter appears to affect the rate of removal and berry weight, although these are not fully explainable.

2.5 Year 2000/01 Activities

Hand Held Leaf Harvester

The hand-held leaf harvester was designed in 1999 and fabricated early in 2000 in preparation for the summer growing season. The harvester consists of two counter-rotating brushes, hydraulically driven and mounted on an adjustable head, such that their degree of intermeshing contact could be varied. Each brush had 2.375-inch long bristles on a 4.625-inch diameter hub. Three different bristle materials were tried, all with a different stiffness. The unit was designed to provide various brush rotational speeds. Brush speed was measured for adjustment by use of a strobe light.

The bristle materials tested were:

- 0.028-inch poly bristles
- 0.040-inch poly bristles
- 0.060-inch nylon bristles

The rotational speeds were:

- 140 rpm
- 340 rpm
- 525 rpm

The degrees of intermesh provided were:

- Bristle tips just touching (no intermesh)
- Bristle tips halfway through other brush (50% intermesh)
- Bristle tips touching other brush hub (100% intermesh)

Figures 8, 9 and 10 below show the hand-held leaf harvester as it was designed and constructed for use in the 2000 test season.

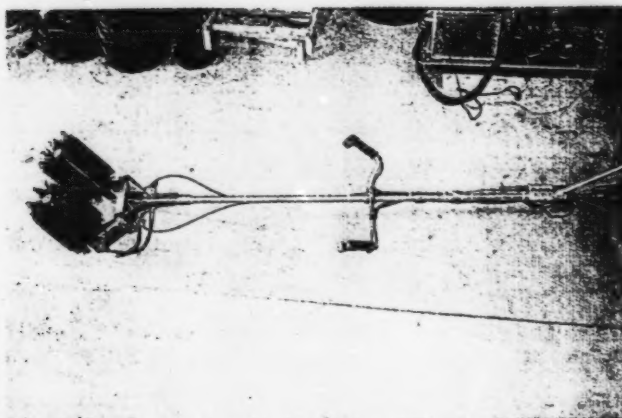


Figure 8. View of the prototype hand-held leaf harvester.

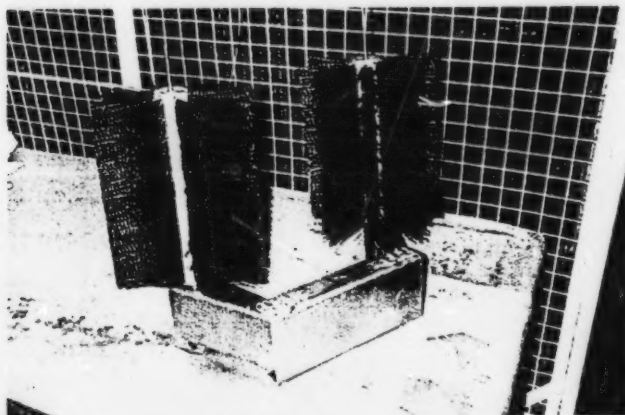


Figure 9. View of brush head.



Figure 10. View of hand-held leaf harvester in operation.

Method of Data Collection: A tarp was laid on the ground in front of a Sea Buckthorn tree. The leaf harvester was used at one of the preset frequencies, brush spacing, and brush types to strip leaves from the trees for 40s. The leaves were gathered from the tarp and placed in sealed plastic bags. A second bag was used to gather any small bits of branch and stems that were removed from the tree during the harvesting process. The process was repeated on different trees for each combination of brush type, speed of rotation, and brush spacing. The testing occurred on July 5 - 7, July 11 - 13, July 25 - 26, and August 18, 2000.

The leaves were measured on a mass basis and recorded as "harvest". The stems and branches were counted and weighed, and were recorded as "damage." The data was then entered into a spreadsheet. The spreadsheets are too large to include in this report. They can be made available on request, as Excel Files on CD.

Test personnel conducted several tests of hand harvesting leaves, without use of the leaf harvester. These tests were conducted in order to get an approximate comparison of the machine's work rate compared to manual methods.

Results and Discussion: Analysis of the data appears to show that rotating brushes are a viable method of removing leaves from Sea Buckthorn trees. The harvester was capable of harvesting up to ten times what inexperienced pickers could harvest by manually. The various design parameters listed above were evaluated in tests. Test results are described in following paragraphs and figures. Each figure shows two graphs. The graph on the left shows harvest as affected by the design parameter, while the one on the right shows damage (as a percent of harvest material) as affected by the parameter.

Figure 11 shows effect of bristle type on the amount of leaf material harvested, as well as damage, which includes non-leaf material removed from the tree. The figures show that harvest rate increased substantially as bristle stiffness increased. However, damage also increased, especially with use of the 0.060-inch nylon bristle. In fact, with this bristle the amount of damage material exceeded harvest material overall during the tests.

It is not known if this removal of material will lead to long term damage to the shrub itself. However, less stiff bristles will be considered for future prototypes to avoid the potential for such damage, and to reduce the amount of non-leaf material in the harvest.

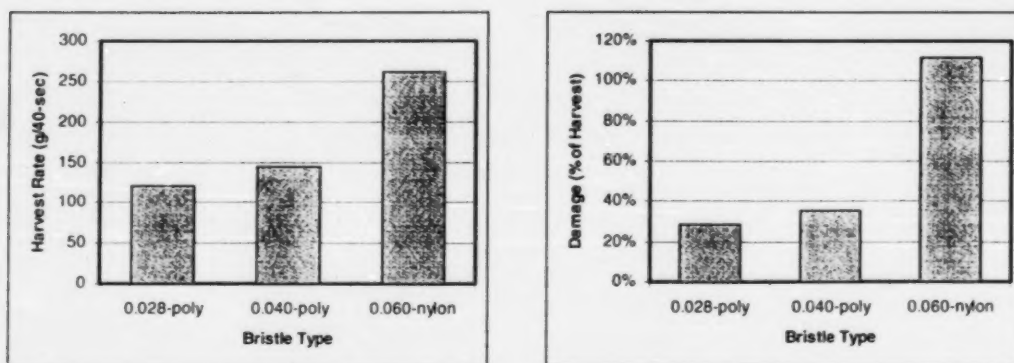


Figure 11. Effects of bristle type on leaf Harvest and Damage.

Figure 12 shows effect of brush speed on harvest rate and damage. The harvest graph shows that harvest rate increases directly with speed over the range tested. The damage graph shows that damage (as a percent of harvested material) also increases with speed, although the effect of higher speeds is not as great as lower speeds.

For a clean harvest, free of non-leaf material speed must be kept very low. However, if damage material is not detrimental speed can be increased to achieve a higher harvest rate.

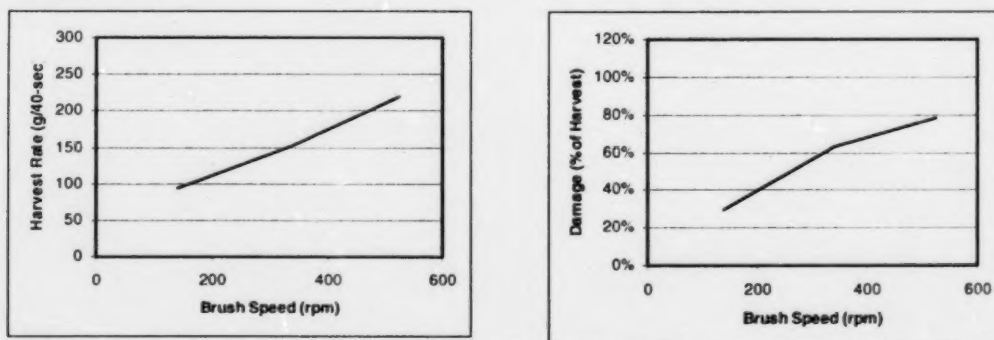


Figure 12. Effects of brush speed on leaf Harvest and Damage.

Figure 13 shows effect of brush intermesh on harvest rate and damage. The graph regarding harvest shows that harvest rate increases directly with intermesh over the range tested. The damage graph shows that damage (as a percent of harvested material) decreases with increase in intermesh from 0 to 50%. At intermesh greater than 50% there is no further effect on damage. Both results indicate that increased brush intermesh has a positive effect on harvester performance, and should therefore be maximized in subsequent designs.

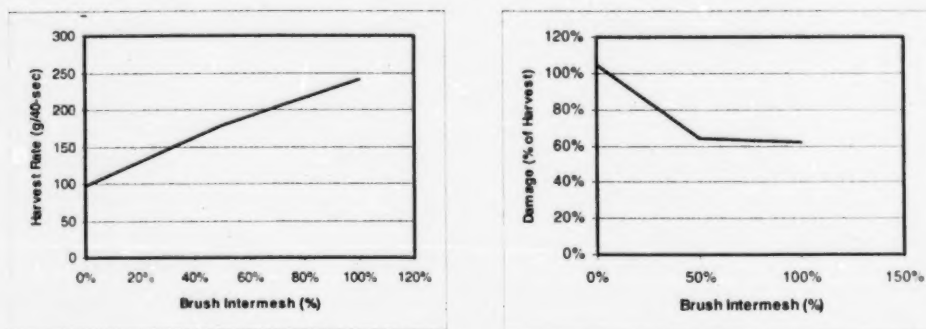


Figure 13. Effects of brush intermesh on leaf Harvest and Damage.

Figure 14 shows a typical branch after leaf stripping has been completed by the harvester. The figure shows complete leaf removal, indicating that this may be a highly effective method for leaf harvesting if it can be scaled up to a commercially feasible size.

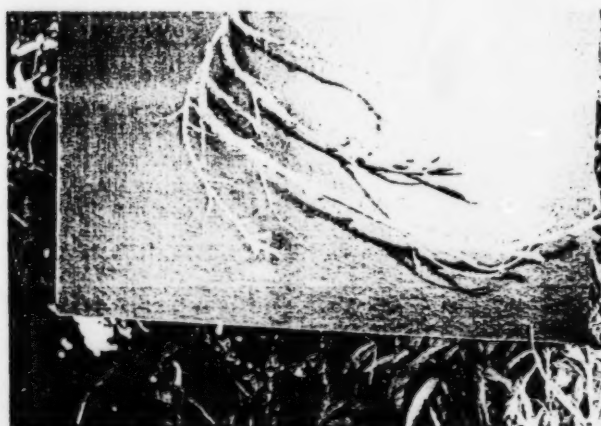


Figure 14. Branch after leaf stripping with harvester.

Full-sized Berry Harvester

A full-size tree shaker was designed and fabricated for field-testing in the autumn of 2000. See **Figure 15** below. The shaker consisted of a vibration mechanism with an attachment device to attach to the tree stalk (**Figure 16**). The vibration device was powered by a hydraulic motor and was driven by a shaft connected to a cam (**Figure 17**). The vibration device was positioned by use of a hydraulically operated arm. This arm has sufficient degree of movement to allow positioning of the shaker at any location on a tree. The arm was mounted on a trailer, together with an operator's control center, and a hydraulic power unit.



Figure 15. The Sea Buckthorn tree shaker.



Figure 16. View of initial "claw" design attached to harvested tree.

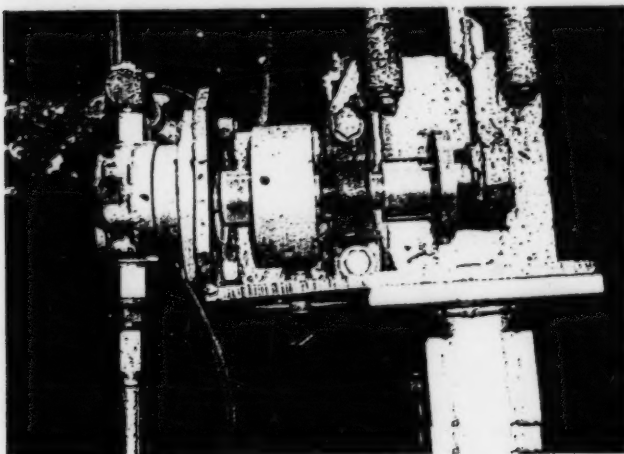


Figure 17. Sea Buckthorn tree shaker cam

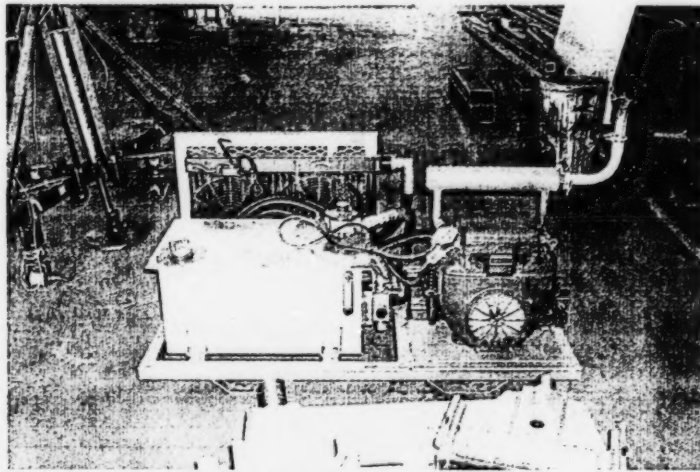


Figure 18. Hydraulic Power Unit

Method of Data Collection: The berry shaker was locked onto the tree trunk approximately 8 to 16 inches above the ground at a point where the trunk shape was suitable. The tree was shaken using the prescribed frequency and amplitude. At each amplitude the machine was run at the lowest selected frequency, and then each successive frequency was tried on the same tree. The berries were collected after each frequency. The harvest for any given frequency was recorded as the berries removed by that frequency added to the total harvest from all the lower frequencies. After all frequencies were tested on a single tree, a new tree was selected and the procedure was repeated at a different amplitude. Testing occurred on October 18 and 19, 2000.

Vibration frequency was determined by measuring the cycles/min of the cam, using a magnetic pickup. Frequencies for each test were set by a hand-controlled valve and could not be exactly replicated for each test. They were set as close as practical within a range and then the exact frequency was measured and recorded in the data.

Amplitude was determined by measuring the offset of the cam, and multiplying by 2.

The frequency ranges were:

- 430 to 500 cycles/min
- 730 to 830 cycles/min
- 1025 to 1150 cycles/min
- 1320 to 1420 cycles/min
- 1530 to 1610 cycles/min

The amplitudes (peak-to-peak) used were:

- 0.75-inch
- 1.00-inch
- 1.25-inch

The berries were collected in sealed plastic bags and the leaves were sorted out. The harvest (berries) and damage (broken branches and stems) were weighed separately and recorded in a spreadsheet. The spreadsheet cannot be presented in this report because of its size. The spreadsheet will be made available on request as an Excel file on CD.

Results and Discussion: Testing on the full-scale berry shaker indicated that shaking satisfactorily removes berries from full-sized trees. Figure 20 shows the effect of shaker frequency on berry harvest. Increasing speed improved the amount of harvest, but above 1400 cycles/min, the increase in damage was much greater than the increase in harvest. As well, most of the berries were already shaken off by this speed so there was little point in going any faster.

The results shown here, for full-sized trees compare very closely with the data obtained in tests of individual branches. Since trees likely have quite different frequency response characteristics than branches the results tend to indicate that branches may not have to be shaken at their "natural frequency" for berry removal to occur.

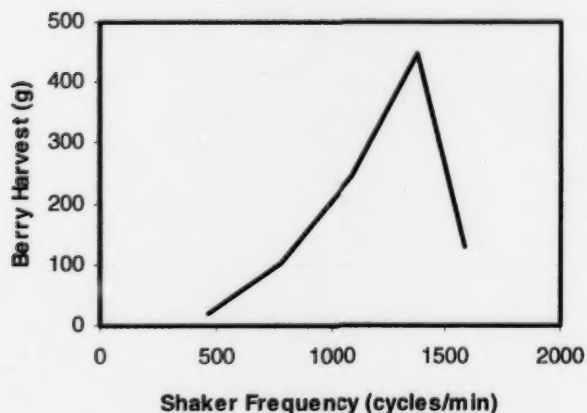


Figure 19. Effect of Shaker Frequency on Berry Harvest.

Figure 20 shows effect of shaker amplitude on berry removal. Increasing the amplitude from 0.75 to 1.25-inches did not appear to give a consistent increase in rate of harvest. This data would tend to indicate that amplitudes higher inches are not required for effective harvest performance.

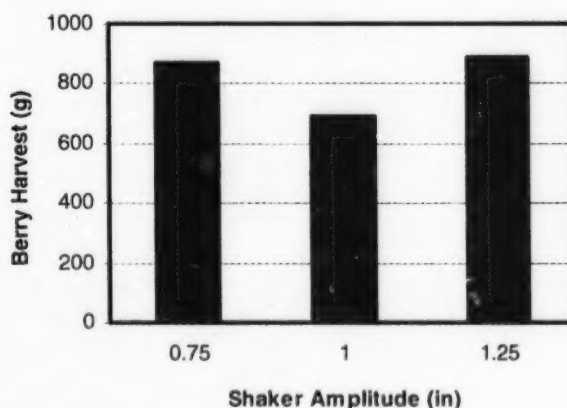


Figure 20. Effect of Shaker Amplitude on Berry Harvest.

Extensive tree stem damage was observed at the point of contact with the shaker attachment device. This damage to the tree bark could provide an entry point for pests or disease, and would need to be avoided in order to sustain a healthy orchard.

After the 2000 test season a new attachment device was developed in an attempt to minimize this damage. The two aspects of re-design were:

- to lower the angle at which the shaking arm extends off the trailer, so the attachment device intercepts the tree at a right angle.
- to improve the contact area and material to be gentler on the bark.

2.6 Year 2001/02 Activities and Results

Full-Size Leaf Harvester

The full-size leaf harvester, designed and constructed, consists of two counter-rotating mandrills with 36-inch long, round plastic brushes **Figure 21**. The brushes could be changed by sliding them in and out of the mandrills. This allowed the use of two different types of brushes for testing.

The mandrills were driven by two hydraulic motors fixed in the harvester head. Brush speed was varied by a flow control valve. The motors and mandrills were adjustable to squeeze the tree inside the brushes. This motion was achieved by using a small electric motor to turn acme-threaded rod fastened to each motor **Figure 22**.

Leaf collection hoppers were constructed to fit over the brush head. The hoppers were fabricated of metal with brushes mounted on the tips to help collect the leaves. The hoppers were curved around the top of the brushes and then funneled down to a 4-inch diameter chute, where a bag was attached to gather the sample. The leaf collection hoppers are shown in **Figure 23**.

The harvester is mounted on an 8-ft hydraulic arm, which could extend and rotate **Figure 24**. The arm could also move vertically from the ground to 8-ft high at full extension. The hydraulic arm and head were mounted to a flat deck trailer, which could be pulled with a truck. The arm was powered by a hydraulic power supply. It consisted of a 14hp gas-engine driving a 8GPM hydraulic pump. The hydraulic power supply had a flow valve built into it to adjust the speed of the hydraulic arm. Having control over the arm speed allowed the leaf harvester to move through the tree at a uniform speed.

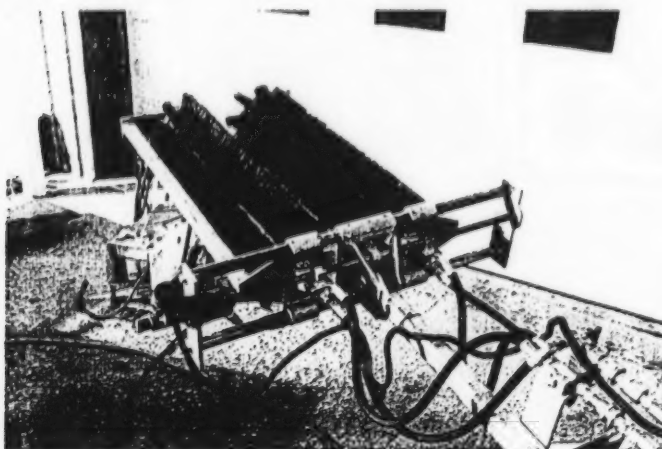


Figure 21. Leaf harvester head, showing brushes.

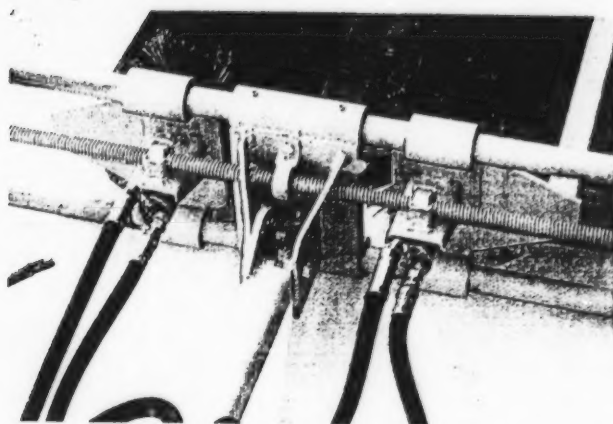


Figure 22. Leaf harvester head, showing brush movement device

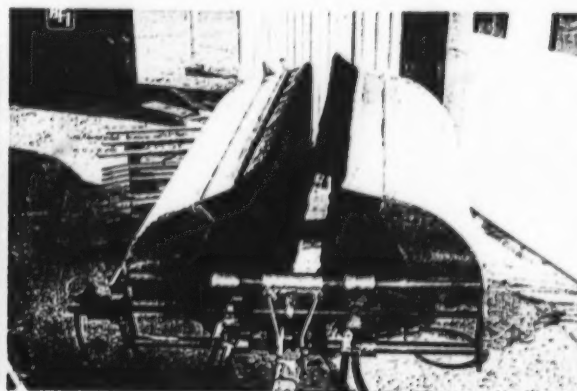


Figure 23. Leaf Harvester head, showing collecting

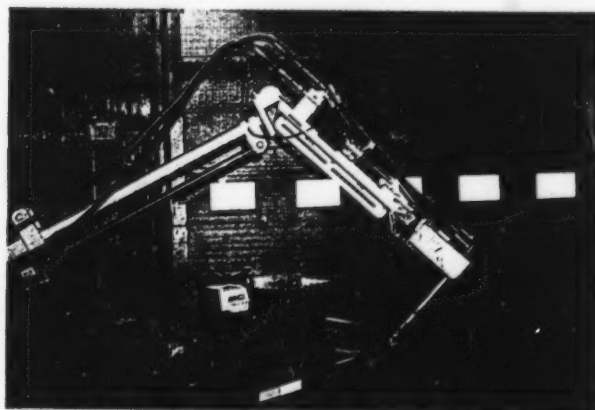


Figure 24. Leaf harvester head support arm.

Method of Data Collection: Trials were conducted July 10-11, July 19-20, and August 16-17, 2001 at the Hymen Sea Buckthorn Orchard at the PFRA Shelterbelt Center. The 5-year old orchard trees were on average 7-ft tall, unpruned and of the cultivar "Indian Summer." They were grown in rows about 7-ft apart. The trees were spaced roughly at 3-ft intervals. Due to the lack of pruning, many of the trees were very bushy and in areas completely filled in the gap between the trees making the positioning of the leaf harvester much more difficult. Testing procedures were designed to work in the orchard setting described above, as follows:

- For each trial, a random tree of an adequate height and width to fit the harvester was chosen.
- A tarp was spread around the base of the tree and the plastic sample bags were placed on the bottom of the collection hoppers (Figure 25).
- Brush type and brush speeds were selected. The brushes are opened as wide as possible and positioned around the tree at the height where the leaves begin. The brushes are then brought together until they touched the tree. Two measurements were then taken; the height from ground to the center of the head and the center-to-center distance of the brushes.
- Brush rotation was initiated and at the same time the operator started moved them together and upward toward the top of the tree. A rate of upward motion was chosen with the flow valve for the arm so that at the end of the trial (top of the tree), the brushes were fully closed.
- The material collected from the hoppers and the tarp around the base of the tree was placed in sealed Ziploc bags. The bags were frozen until sorting and analysis could be done.
- A second pass was done on the trees during the 2nd and 3rd trial (July 16-17 and August 16-17, 2001) with the brushes positioned 90 degrees (about a vertical axis) to the first pass. The above procedure was again used.



Figure 25. Leaf harvester tests in operation.

In addition to harvest data, an assessment was also done to determine the amount of damage to the trees. A scale from one to three was used to make this assessment, as shown below. All trees were assessed using these guidelines after which the points were averaged to give an overall score.

Branch damage

- | | |
|---|-----------------------------|
| 1 | 1-24% of branches damaged |
| 2 | 25-74% of branches damaged |
| 3 | 75-100% of branches damaged |

Bark Damage

- | | |
|---|---|
| 1 | light damage (barked rubbed) |
| 2 | medium damage (some Scraping of outer bark) |
| 3 | heavy damage (complete disruption of vascular tissue) |

Leaf damage

- | | |
|---|------------------------------|
| 1 | 0-24% of leaf buds damaged |
| 2 | 25-74% of leaf buds damaged |
| 3 | 75-100% of leaf buds damaged |

Over-all condition of the tree

- | | |
|---|---|
| 1 | no change in condition from untested tree |
| 2 | less vigorous than non-tested trees but no serious damage visible |
| 3 | less vigorous than non-tested trees with serious damage present |

Results and Discussions: Figure 26 shows the overall effect of the machine parameters on leaf harvest performance.

Harvest (g)	Brush	Speed
Brush Type	350 RPM	500 RPM
0.028-inch	112.7	188.9
0.040-inch	415.2	510.4

Figure 26. Mean harvest of Sea Buckthorn leaves during the first pass over the 3 trial dates.

The harvest increased significantly when the brush type was changed from 0.028 to stiffer 0.040 inches at both 350 and 500 RPM. The 0.040-inch brushes were able to reach in and remove more leaves from the center, whereas the 0.028-inch brushes removed mainly the leaves from the outside. The increase in harvest was also significant when the brush speed was increased from 350 to 500 RPM using either brush type.

About 40 to 60% of the leaves were removed in all tests except 0.040-inch at 500 RPM. This would indicate that damage to the tree by over-harvesting would not pose a problem under these parameters. When 0.040-inch brushes were used at 500 RPM 70 to 90% of the leaves removed. This left the trees virtually bare and problems associated with over harvesting were therefore anticipated.

The material other than leaves (debris), removed by the harvester is shown in Figure 27 was less dependent on the machine's aggressiveness than on the harvest.

Debris (g)	Brush	Speed
Brush Type	350 RPM	500 RPM
0.028-inch	3.9	10.0
0.040-inch	22.3	117.6

Figure 27. Material other than leaves removed from Sea Buckthorn trees during the first pass of the leaf harvest over 3 trial dates.

While debris removal increased with harvest, the only significant difference occurred when the brush speed was set at 500 RPM and the 0.040-inch brush type selected. There was a much greater spread in the data than the harvest data.

The greater variability in the debris data was caused both by the random shape of the trees and the less precise nature of the debris variable.

None of the trees scored a 3 regarding damage, and the overall average damage score was 1. At even the most aggressive setting, the harvester did not appear to extensively damage the trees. Some smaller branches were broken off when they were wrapped around the brushes, but is not expected to be a significant problem.

The harvester did cause some damage to the bark of the trees. Most of the damage occurred when the outer branches pushed through the brushes to the mandrill, and in such cases only the outer covering of the bark was damaged. However, in some cases the bark was scraped down to the hardwood. This is cause for concern as it provides a means of entry for insects and disease.

Figure 28 shows leaf collection in the hoppers as well as leaf loss that escaped from the collection system. In general, about three-quarters of the leaves removed by the brushes were collected in the system, and about one-quarter were lost.

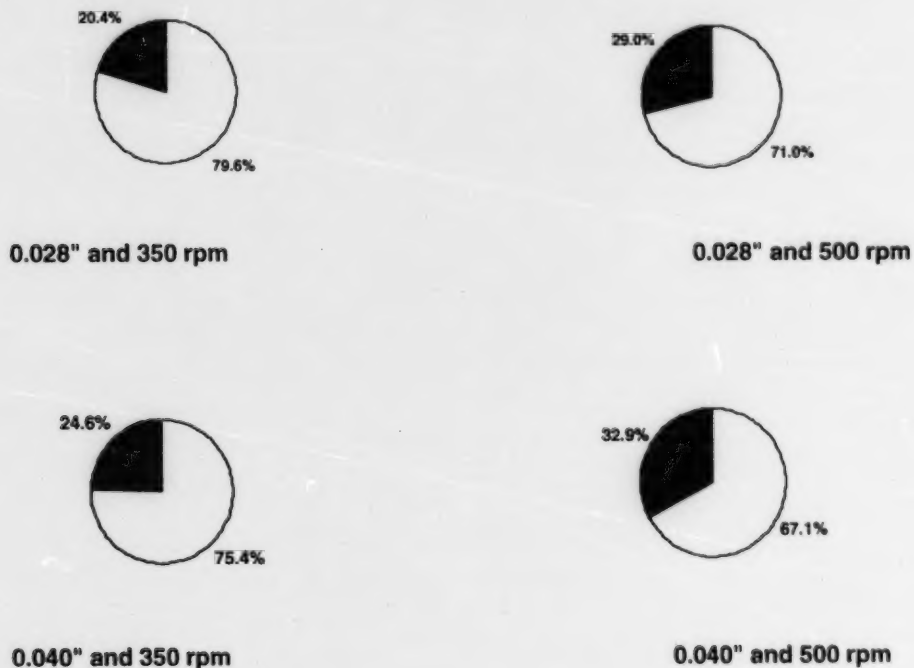


Figure 28. Percentage of Sea Buckthorn leaves collected (dotted) and missed (solid) by the brush-shield system during testing in 2001.

The leaves that were not collected tended to be spun completely around the brushes and out the bottom where the hoppers did not reach, while others were lost out the back of the brushes. While collecting all the leaves that are removed from the tree is unlikely, shielding the back of the machine and wrapping the hoppers closer to the base of the brushes could reduce the collection losses. Another potential improvement might be to place a vacuum on the bottom of the hoppers to suction all the leaves in. This would also provide the means for moving the harvested leaves from the brush head to a storage tank.

Higher brush speed tended to increase loss out of the hoppers. This was probably due to the greater force imparted to the leaves by the higher speed. Thicker bristles tended to increase loss, but to a lesser extent than brush speed.

Second passes were made on the harvested trees on all dates. However, a lack of hydraulic power to the harvester arm resulted in incomplete data, and it was therefore not used in the analysis.

Figure 29 shows debris removed during second-pass harvest. The debris removed by the second pass was less than the original pass, with the exception of 0.028-inch bristles at 500 rpm. At the most aggressive setting (0.040-inch at 500 rpm) the amount of debris dropped from 117.6 to 34.6 g.

Debris (g)	Brush Speed	
	350 RPM	500 RPM
Brush Type		
0.028"	0.4	16.8
0.040"	13.3	34.6

Figure 29. Mean debris removed from Sea Buckthorn trees during second pass of the leaf harvest trials on August 16-17, 2001.

Modified Berry Harvester

The berry harvester **Figure 32** was modified in two ways for the 2001 harvest season:

- a new tree-attachment claw was designed
- a new shaker actuator was designed and constructed

The new claw used to attach the actuator to the tree was designed and fabricated by PAMI personnel. This claw was very important because in previous years the claw significantly damaged the bark of the tree. The new claw consisted of a steel tube machined to a 2-inch inside diameter, and cut in half along its length. Aluminum bushings were fit into the steel halves.

Sets of these bushings were bored out to $\frac{3}{4}$, 1 and 1 $\frac{1}{4}$ -inch. They were cut in half along their length similar to the steel tubing, and were lined with rubber in order to grip the tree. The outside diameters of these bushings were machined so that they could rotate and slide inside the steel tube to relieve stress on the tree bark. The bushings were easily removed to allow quick changeover for different sized trees. **Figure 30** shows the new claw.

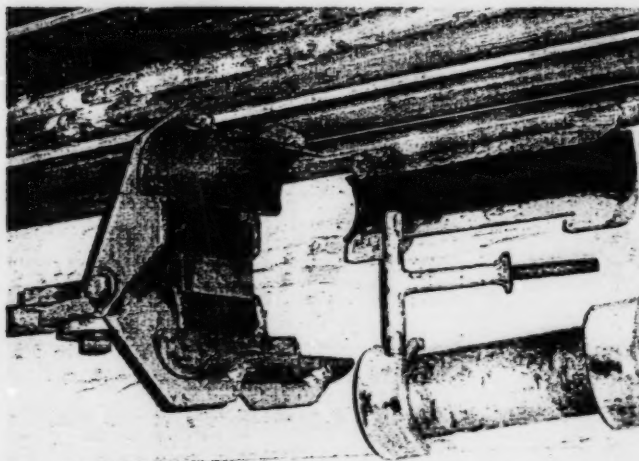


Figure 30. View of re-designed "claw".

To achieve the shaking motion of the tree an electro-hydraulic actuator was used. This actuator was designed to put out three different motion modes:

- triangle wave
- square wave
- sin wave
- A remote electronic control module allowed adjustment of both the frequency and the amplitude of actuator stroke. A portable scope meter was used to measure actuator stroke. The actuator had an amplitude of 1-inch and a frequency range of 1 to 50 Hz.

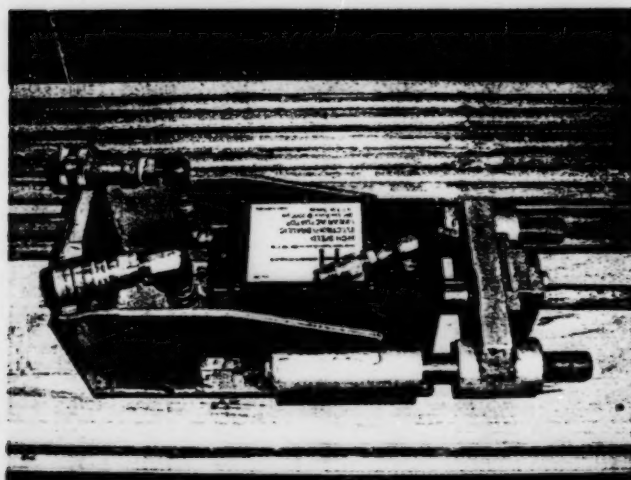


Figure 31. View of electro-hydraulic actuator.



Figure 32. View of re-designed "claw" attached to harvested tree.

Method of Data Collection: Trials were conducted September 5-6, September 12-13, September 26, October 31, and November 1, 2001 in the Hymen Sea Buckthorn Orchard of the PFRA Shelterbelt Center, at Indian Head, Saskatchewan. The 5-year-old orchard trees were on average 7-ft tall, un-pruned and of the cultivar "Indian Summer." Tree rows were about 7-ft apart, and trees were spaced roughly 3-ft apart in each row. The un-pruned trees were very bushy and in some areas completely filled in the gap between individual trees, making the positioning of the collection baskets quite difficult.

For each trial, a random female tree of an adequate size was chosen. Trees were selected with a main branch or trunk that had at least 8-inches of trunk with no branches in order to attach the claw without damaging the tree. Collection baskets, designed fit around the base of the tree were used to collect the fruit and debris.

An appropriate claw insert was selected to fit around the tree, and the shaker actuator was set to the chosen amplitude and frequency. The claw was then positioned and fastened manually, as close to the bottom of the tree as possible.

The Actuator was started and run for 5 seconds After this 5-second trial was completed, the berries and debris from the hoppers were collected into bags. The actuator was again turned on and run for 15 seconds and the harvest collected. The actuator was then run for 60 seconds. Again, all berries and debris were collected and bagged.

After the harvest was collected, the apparatus was moved to the next tree, where a different amplitude and/or frequency were used. The frequencies chosen for tests were:

- 1200 cycles per minute (20-Hz)
- 1500 cycles per minute (25-Hz)

These frequencies were chosen from pre-trial observations during frequent sweeps, and agree closely with previous years testing.

The amplitudes (peak-to-peak) used with the new shaker actuator were:

- 1.0-inches, for the 25-Hz trials
- 1.4-inch for the 20-Hz trials

The samples were manually sorted into two classifications; harvest, and debris. The "harvest" consisted of the berries and "debris" consisted of bark, stems, and branches. The harvest and debris samples were weighed., and the data inputted into a data spreadsheet.

Results and Discussion: Figure 33 shows the effect of shaking time on berry harvest.

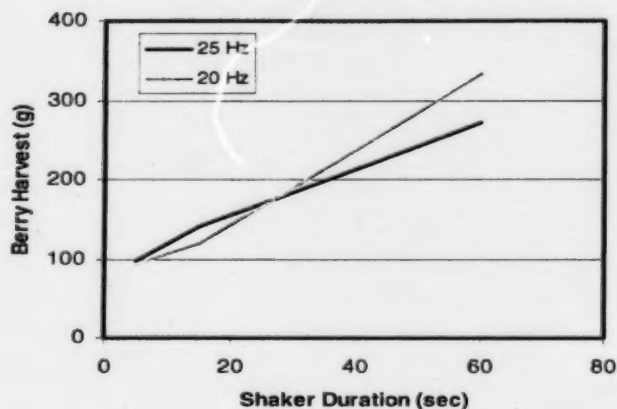


Figure 33. Average harvest of Sea Buckthorn Berries over the 4 trial dates.

It was apparent during all 4 trial dates that berry harvest increased directly with duration of shaking. There appeared to be a roughly linear relationship between the 5, 15 and 60-second harvest levels, indicating that no "diminishing return" characteristic in harvest rate had been reached over the 60-second time period.

As shown **Figure 34**, berry harvest per tree significantly increased in relation to the time of year. This seemed to be related to the consistency of the fruit. As the year went on the berries grew softer and would break away more readily. This was the main reason for the increase in harvest. As the year went on however, the quality of berries decreased. This progressed to the point where the last harvest contained mostly broken berries. This indicates that care must be taken to find the optimum harvest time for maximum berry yield and quality.

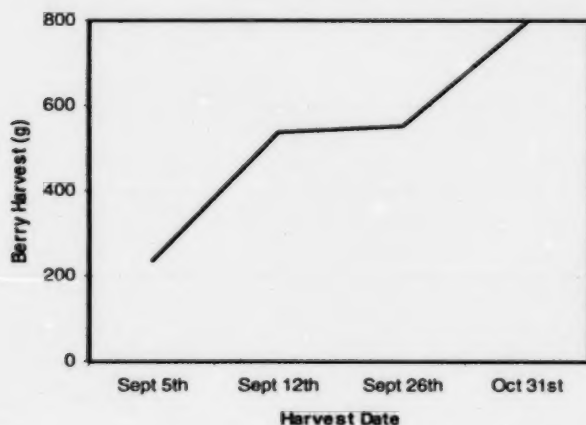


Figure 34. Effect of harvest date on berry harvest.

The harvester was attached to individual branches of the Sea Buckthorn tree, and was successful in removing virtually all berries from the branch it was attached to. However, it removed virtually no berries from adjacent branches. To be commercially viable the harvester will need to shake all branches of a tree at once. There are two possible solutions to this:

- attach the claw to various different branches and shake them one at a time
- prune the tree such that there is a single main trunk at the bottom where the shaker could attach

Both of these options would allow us to harvest a greater percentage of the berries. The pruning option, although long-term would likely give greater harvest efficiency.

Figure 34 shows effect of shaker amplitude and frequency on debris content in the berry harvest over the test season. Debris content was quite low for all machine settings and harvest durations, especially earlier in the year. The greatest debris occurred at the highest amplitude and lowest frequency (1.4-inch for the 20-Hz).

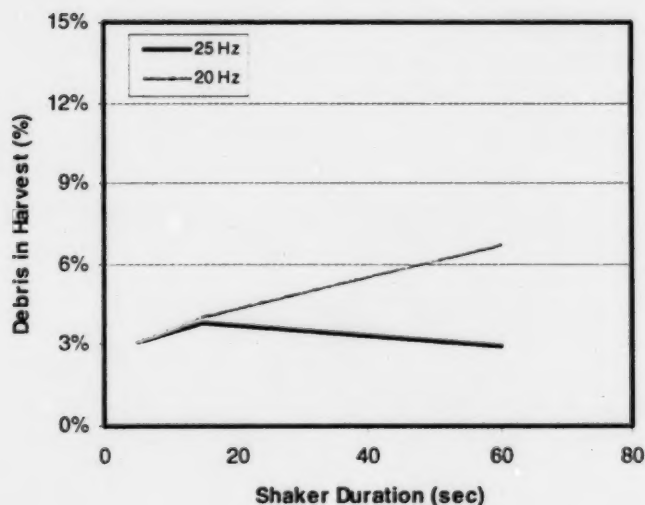


Figure 35. Effect of Shake duration on debris content in berry harvest.

The majority of debris for either setting were branch tips that had broken off during the trial. This was more predominant in trees that had a large quantity of berries near the end of the branches. The damage was quite visible after the test was completed. The damage appeared to be most dramatically related to the time of year of the harvest. As shown in **Figure 35** - the later in the year, the more branches that were broken off.

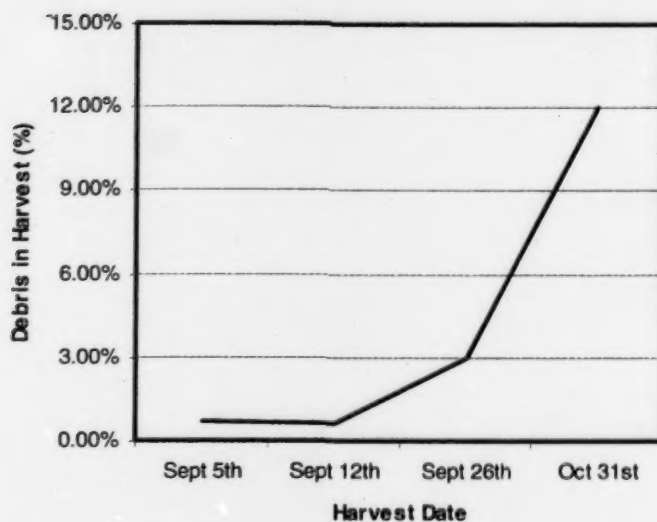


Figure 36. Effect of Harvest date on debris content in berry harvest.

Tree damage was rated using the damage assessment process described earlier in this report. Although the damage was noticeable, none of the individual trees were rated at 3, and the overall damage of all trees together was rated at 1.5. Some trees had high branch damage as mentioned above. These trees were harvested later in the fall. Bark damage was almost non-existent with use of the new redesigned claw. Although long-term effects are not yet known, this type of harvester appears to be useable without greatly affecting the tree.

3. Conclusions and Recommendations

This project demonstrates that Sea Buckthorn harvesting can be successfully carried by mechanical means. Berry harvesting can be effectively accomplished by tree shaking. Leaf harvesting can also be effectively accomplished by tree brushing. Detailed parameters for design of harvest machines were determined first on a small scale, and then with scaled-up prototypes. A discussion of these parameters follows.

Berry Harvester

From the data, parameters for tree shaking were determined for maximum harvest and minimum damage to the tree. The best shaking frequency was in the range of 25-Hz, while an amplitude (peak-to-peak) of 1-inch was determined to most suitable. At this frequency and amplitude best overall results were achieved with respect to maximum harvest and minimum damage.

The data also showed that time of harvest is critical in maximizing berry quality and minimizing tree damage and amount of debris in the harvest. The data from 2001 indicates that harvesting early to mid September can produce highest berry yields, and harvest-to-debris ratios of approximately 150:1. Harvest-to-debris ratio drops rapidly to 30:1 in late September, and 10:1 in early October. Large harvest yields experienced later in the season were offset by low berry quality and high debris and increased tree damage.

Shaker attachment to the tree was found to be critical in minimizing tree damage. A firm grip to eliminate rubbing by a flexible contact material (like rubber) to absorb pressure points was most successful. Additional work must be done to streamline the tree attachment process, either by quick-attach devices, or by some other tree contact method that prevents bark damage.

Orchard layout and pruning is also critical to harvest efficiency. Aligning trees in rows, and pruning lower trunks to give a consistent shaker attachment point would greatly enhance harvest rate.

Required duration of tree shaking was determined to be about 60-seconds for substantial berry recovery. This parameter will be useful in determining harvest rates, and other aspects of harvester design.

A collection system is needed to speed up the gathering of the harvested berries. The system should be integrated into the harvester, and should contain means to convey the berries into a storage container. The system must be gentle enough to minimize damage to the berries.

Leaf Harvester

From the data the best parameters were determined for maximum harvest and minimum damage to the tree. The best combination was the 0.04-inch bristle brushes, rotating at a speed of 350 RPM. This produced a good harvest rate and harvest-to-debris ratio of 18:1. Speeding up the brushes to 500 RPM increased the harvest rate by about 20% but greatly reduced harvest-to-debris ratio to about 4:1. This substantial increase in damage was not worth the increase in harvest rate.

The hoppers were very effective in collecting the leaves. They did miss more as the brush speed picked up but over all they were successful. Future leaf harvester designs must contain integrated hopper systems, that also have means to convey the leaves into storage containers.

Orchard layout and pruning will be critical to leaf harvest efficiency. Trees aligned in rows and trimmed to uniform width and with a single lower trunk will allow design of much more automated leaf harvesters, with greatly increased harvest rates.

4. Background Literature

Li, T. S. C., and W. R. Schroeder. 1996. Sea Buckthorn (*Hippophae rhamnoides* L.): A Multipurpose Plant. *Horticulture Technology*. 6(4): pp. 370-380.

Olander, S. Mechanical Harvesting of Sea Buckthorn. Schroeder, W. R., and Y. Yao. 1995. Sea Buckthorn: A promising multi-purpose crop for Saskatchewan. Prairie Farm Rehabilitation Administration Publication.

5. Communication of Results

Presentation, Interim Results: Over the course of the project a number of presentations have been made regarding the project. These are listed following. Effort was made to acknowledge the support received from the Saskatchewan Agricultural Development Fund and the Manitoba Rural Adaptation Council:

- A poster was displayed In March of 2000 during a poster display session of agricultural research and development at the University of Manitoba.
- A poster was displayed in July 2000 at the Agri-Food 2000 conference in Winnipeg, Manitoba.
- A presentation was given in September 2000 on the development of the brush leaf harvester at the ASAE North Central meeting in Moorhead, Minnesota.
- A presentation was given in September 2000 on the development of the prototype berry harvester at the ASAE North Central meeting in Moorhead, Minnesota.
- A presentation on the project was given in December 2000 at the Manitoba Sea Buckthorn Association annual meeting in Portage la Prairie, Manitoba.
- A demonstration was given of the prototype berry and leaf harvesters at PAMI's 25th Anniversary Celebration October, 2000.
- A demonstration of the harvesters was given at the PFRA Booth100th Celebration Event, July 2001.
- A poster display was carried out at "Heart of the Continent Trade Show" in July 2001.
- A presentation and poster display was given at the University of Manitoba Faculty of Bio-systems Engineering, November 2001.
- A presentation was given to the Manitoba Sea Buckthorn Association in December 2001.
- A presentation entitled "Evaluation of a prototype Sea Buckthorn Harvester was given at a PFRA Workshop in Indian Head, March, 2002.

Publication, Final Results: A publication, known as a "PAMI Research Update" will be developed, printed and distributed to subscribers.

Website Posting: The document described above will be posted in a down-loadable format on PAMI's website.

News Release: A news article will be prepared and released to approximately 200 news agencies in Saskatchewan and Manitoba over the next 4 months. The article will highlight the project results and will acknowledge the funding agencies.

Industry Update: Information packages regarding the project will be sent to Industry Associations and equipment manufacturers to help in the further development and implementation of the technologies.

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